Evaluation of Image Resolution of Aerial Image Formed with AIRR Based on Slanted Knife Edge Method

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1. Introduction

Aerial display [1], which forms a floating information screen in mid-air, is expected to realize touchless aerial interface that is immune from hygiene issues on pressing a button to operate machines. We have proposed aerial imaging by retro-reflection (AIRR) [2] to form an aerial image that features a wide viewing directional range. AIRR uses a retro-reflector to converge light in mid-air. The sharpness of the aerial image depends on the diffraction patterns of the retro-reflector [3].

The purpose of this paper is to evaluate the image resolution of aerial image by use of the Modulation Transfer Function (MTF). We utilize a slanted knife edge method [4] to measure MTF. We report the difference in MTF of aerial images formed by use of retro-reflectors for sensing and for aerial display.

2. Slanted knife edge method

MTF is calculated based on the process shown in Fig. 1. The slanted knife edge method [4] estimates the MTF curve by calculating a region of interest (ROI) in a recorded edge image, which is the image of a slightly slanted knife edge illuminated by a uniform divergent light.

3. Experiments

3.1. Experimental Setup

Fig. 2 shows the experimental setup for MTF measurement. We examined two types of retro-reflectors: a retro-reflector for sensors (NikkaliteCRG) and a retro-reflector for aerial display (RF-Ax), both of which were produced by Nippon Carbide Industries. A digital camera was used for a 2D light measuring device. Its exposure time is 1/20 seconds. In order to examine the change in the MTF curve depending on the incident angle to a retro-reflector, the retro-reflector was rotated from 0 to 90 degrees in 15 degree increments.

3.2. Experimental Results

Fig. 3 shows the MTF curves for each angle in each aerial image formation technique. It is shown that the MTF curve changes by rotating the retro-reflector. NCRG has a high degree of decrease in MTF, but has a wide viewing angle for observing aerial images. The resolution of aerial image was successfully indicated by use of MTF.

4. Conclusions

We have measured MTF of aerial imaging optics. The image resolution of the aerial image formed with AIRR was successfully expressed by use of MTF.

References

[1] International Electrotechnical Commission, “3D display devices Part 51-1: Generic introduction of aerial display,” IEC TR 62629-51-1 (2020).
[2] H. Yamamoto, *et al.*, *Opt. Exp.* **22**, 26919 (2014).
[3] N. Kawagishi, *et al.*, *IEICE Trans. On Electronics* **E100-C**, 958 (2017).
[4] N. Kawagishi, *et al.*, Proc. IDW’19, FMCp-4-7L (2019).

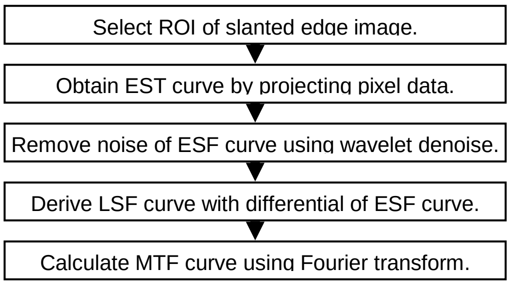


Fig. 1 Slanted edge method for calculation MTF.

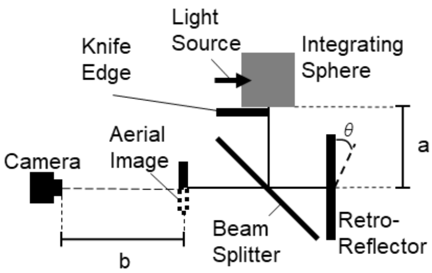
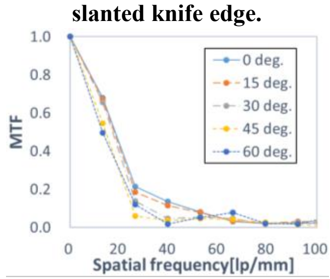
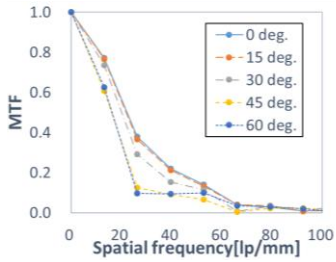


Fig. 2 Experimental setup to obtain the aerial image of a slanted knife edge.



(a) NikkaliteCRG



(b) RF-Ax

Fig. 3 MTF curves in AIRR by use of (a) a retro-reflector for sensor and (b) a retro-reflector for aerial display.